THE PRECIPITATION PATTERN ASSOCIATED WITH AN ATLANTIC COASTAL STORM

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INTRODUCTION

A surface wave which developed in the western Gulf of Mexico on February 25, 1952, moved northeastward across the Gulf to northeastern Florida. During the following 3 days it deepened and moved northeastward off the Atlantic Coast of the United States. This storm produced a wide area of rain over the Gulf States while the storm moved toward the East Coast but as it moved up the East Coast the rain changed to snow and, at the same time, the precipitation pattern over land narrowed considerably.

The narrowing of the coastal precipitation pattern combined with the threat of a moderate to heavy snowfall, presented a difficult problem to the forecasters in many of the major cities along the Atlantic coast, north of Cape Hatteras. This problem is discussed in this article.

Of all the Atlantic coastal regions affected, Cape Cod, Mass., received the heaviest snowfall and suffered the greatest storm damage. This situation is also discussed.

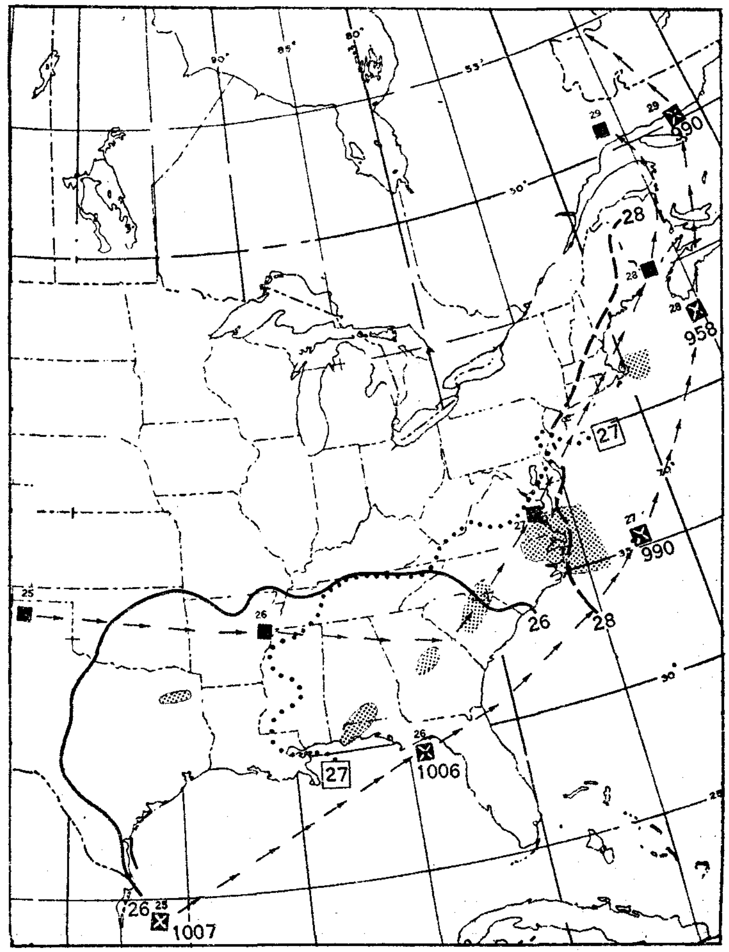

FIGURE 1.—Storm track and precipitation chart for February 25–29, 1952. Precipitation areas are shown for amounts of Trace or more; stippled areas indicate 1 inch or more in a 24-hour period ending the 26th (solid), the 27th (dotted) and the 28th (dashed). Storm tracks at the surface and at the 500-mb. level are shown by arrows. The blocked "X" indicates the 1230 GMT positions and central pressure of the surface Low while the solid blocks represent the 1500 GMT positions of the 500-mb. center.

THE DEVELOPING STORM

In tracing the origin of this storm it is worthwhile to examine the upper air picture prior to the formation of the surface wave in the west Gulf region on the morning of the 25th.

At 1500 GMT, on that date, a small cut-off cold Low, or cold dome, at the 500-mb. level was centered above Amarillo, Tex., while, to the north, a stream of northwesterly winds entered the United States over eastern Montana. Over North Dakota the stream split. The major current swept forward in a cyclonic curve around a Low in the Great Lakes region. The minor branch swept southward and southwestward over the east slopes of the Rocky Mountains toward west Texas and New Mexico, pivoted around the cold dome and proceeded eastward and northeastward to rejoin the major stream over the mid-Atlantic coast. East of the small, cold Low aloft the isotherms and contour lines were in phase from Texas to the Atlantic coast, except for a small area at the center.

All in all, there was no indication of cold air surging southward into the Gulf but rather a sharp change to colder aloft as the upper cold dome passed eastward over each station, followed by a slow recovery to the previous temperature level. Typical of this change to colder was the 24-hour temperature drop at 500 mb. at 3 stations along the Gulf coast: Brownsville, Tex., had a 5° C. change, Burrwood, La., an 8° C. change and Lake Charles, La., reported a 24-hour change from −15.8° to −25.5° C. without any change in wind direction.

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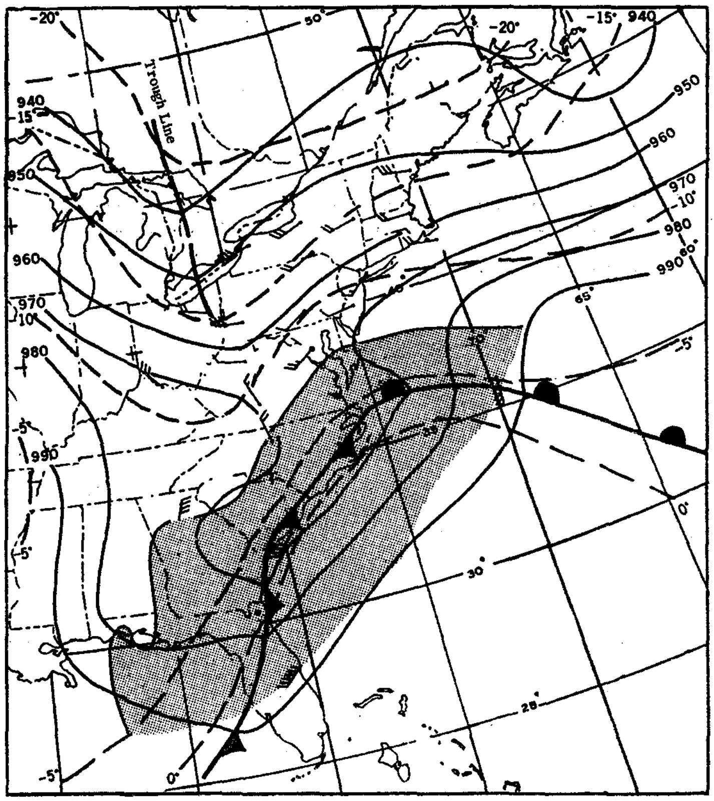

FIGURE 2.—700-mb. chart, 0300 GMT, February 27, 1952. Contours (solid lines) are at intervals of 100 geopotential feet. Isotherms (dashed lines) at intervals of 5° C. Fronts at the 700-mb. level. Barbs on wind shafts are for speeds in knots (full barb = 10 knots). Shading indicates areas of active precipitation at the surface at 0330 GMT.

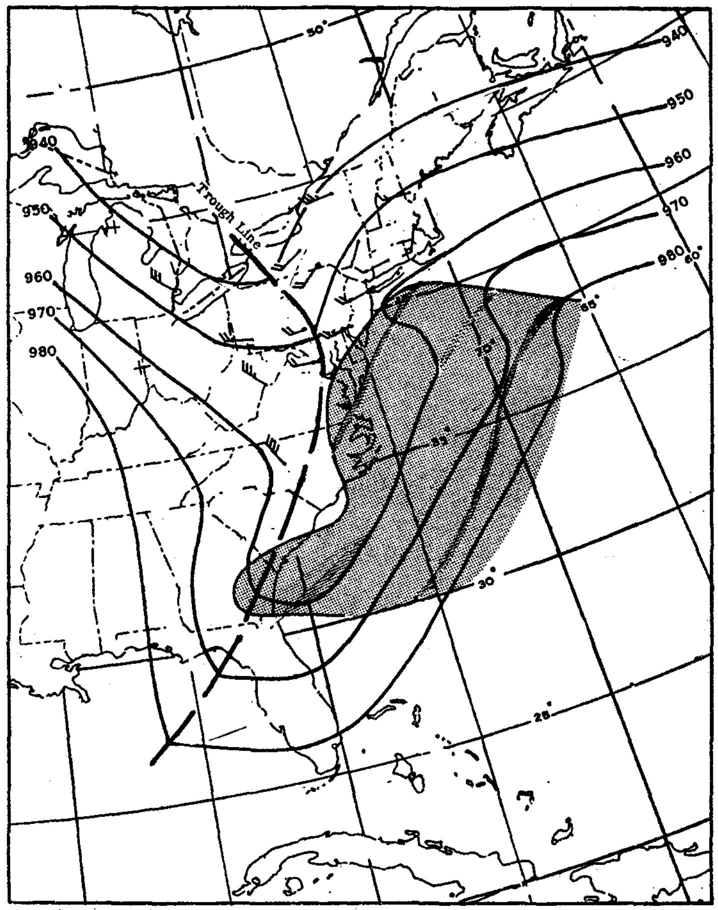

FIGURE 3.—700-mb. chart, 0900 GMT, February 27, 1952. Precipitation at 0930 GMT.

The 1500 GMT soundings on the 24th for Brownsville and Lake Charles showed that the lapse rate from the surface to the arbitrary level of 400 mb, was moist adiabatic for some layers and conditionally unstable for others. At the surface, at 1530 GMT on the 25th, Brownsville had a temperature of 68° F. and a dew point of 66° F., while Burrwood reported a temperature of 60° F. and a dew point of 58° F. Although the surface cold front had just arrived at Brownsville, the surface temperature indicated the presence of tropical air in the vicinity. The air over the northern portion of the Gulf was modified polar air. These conditions prevailed at the same time the cold air had begun to move in aloft. Considering only the air masses, the combination was a propitious arrangement of important factors contributing to the deepening of the surface storm; the necessary moisture supply, instability, and the advection of cold air aloft to intensify this condition.

As the upper center moved eastward from Amarillo, during the following 24 to 36 hours (fig. 1), the associated cold air invaded more southerly latitudes as a result of the sharpening of the upper trough. This intensification of the trough connecting the southern Low with the parent Low to the north resulted in an accentuation of the north-south orientation of the contour lines and formed a new flow pattern which aided in the destruction of the relatively warm air between the cold sources. Ultimately, as the cold air at both ends of the trough amalgamated (figs. 2, 5), there resulted a simpler flow pattern with tropical air to the east and polar air to the west of the trough lines. In other words, by the time the surface wave moved off of the south Atlantic coast it had a vertical structure which promoted the rapid development of the surface storm.

THE PRECIPITATION PROBLEM

The precipitation from the storm (fig. 1) was in the form of rain in the deep South but an increasing proportion of it became snow as the Low moved up the coast. From North Carolina northward, the precipitation was almost wholly snow on the west side of the storm track. This moving area of falling snow presented a problem in forecasting its influence on the various cities along the eastern coast. The problem was complicated by the fact that the occurrence, or nonoccurrence, of snow was a borderline condition for many major cities. There was the further threat that if snow did fall at a station it might amount to as much as 5 inches. Obviously, a small miscalculation on the position of the western limits

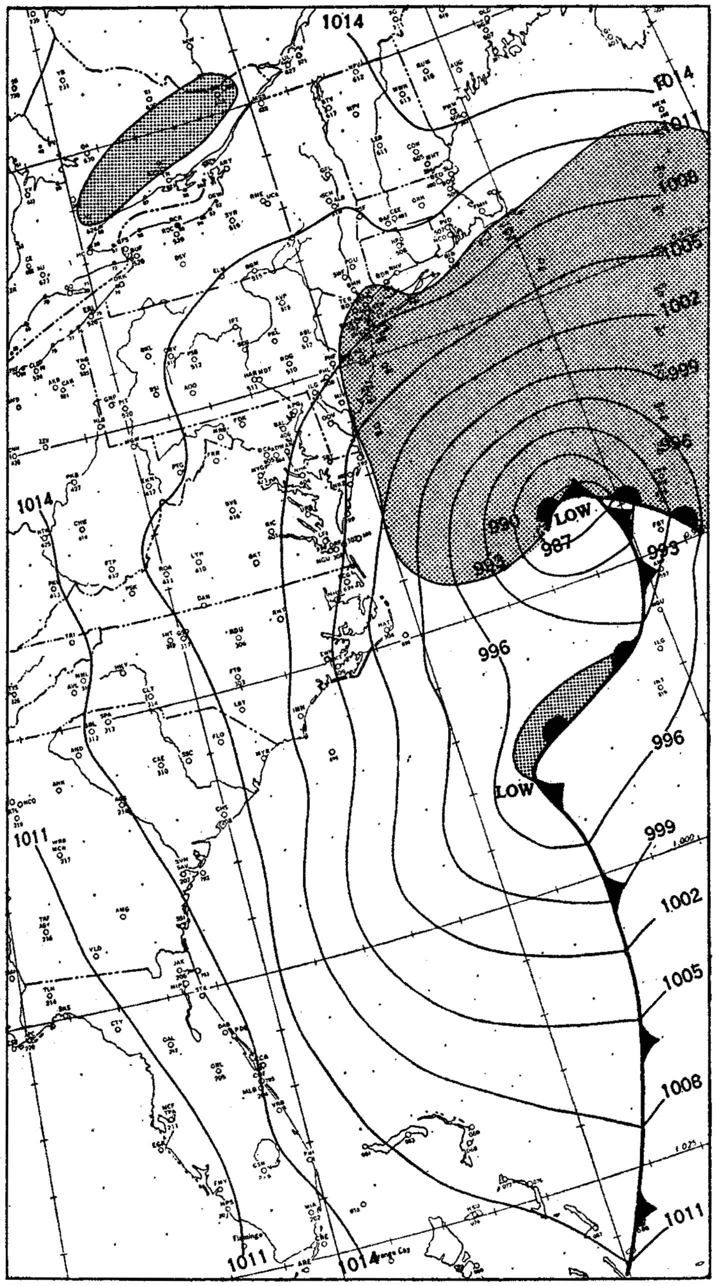

FIGURE 4.—Surface chart, 1500 GMT, February 27, 1952. Shading indicates areas of active precipitation.

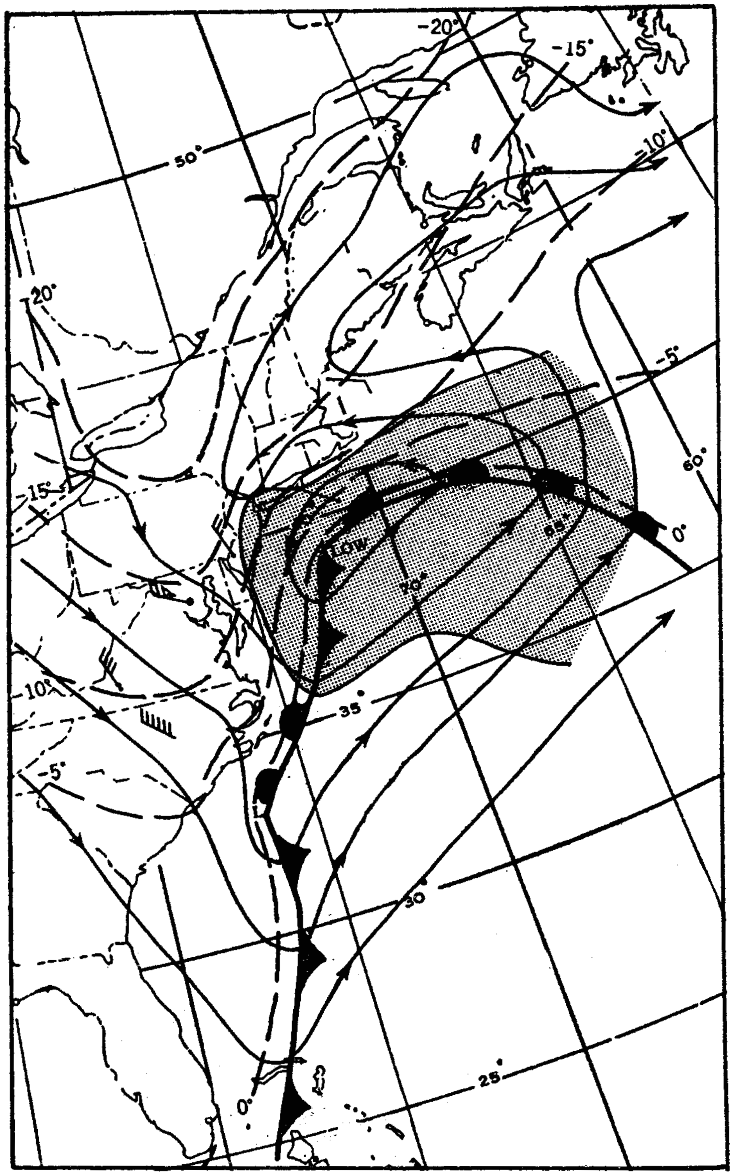

FIGURE 5.—700-mb. chart, 1500 GMT, February 27, 1952. Solid lines show airflow parallel to the contour lines. Precipitation at 1530 GMT.

could lead to a "no snow" forecast followed by a traffic-stalling depth of snow.

Just such a problem was involved in forecasting for Washington in the early morning hours of the 27th when the 0630 GMT map showed snow falling from the southern border of Virginia northward to a short distance south of the District of Columbia. Also, snow was falling east of Washington, at one time, as close as 20 miles away. The official forecast correctly called for snow east of the District in the morning and 2 to 4 inches along the Atlantic-coast of Delaware. Figure 1 demonstrates the borderline conditions the forecasters had to contend with along the mid-Atlantic and New England coasts. Note that from Virginia northward, the distance from the western Trace limit to the areas of 1 inch or more was quite short. In this storm the track of the 500-mb. Low seemed to be the western limit of 1 inch or more precipitation east of the Appalachian Mountains.

From Oklahoma eastward and up the coast this same track remained just east of the western edge of the precipitation area with the distance between the boundary and the track decreasing as the 500-mb. center and the surface center became more nearly aligned in the vertical. It appears that the region of the deepening 500-mb. Low was a center of maximum horizontal convergence in the lower layers of the storm. This activity could account for the relation between the heavy amounts and the upper track. Then, too, as Klein [1] pointed out, "the most important general parameter in determining precipitation

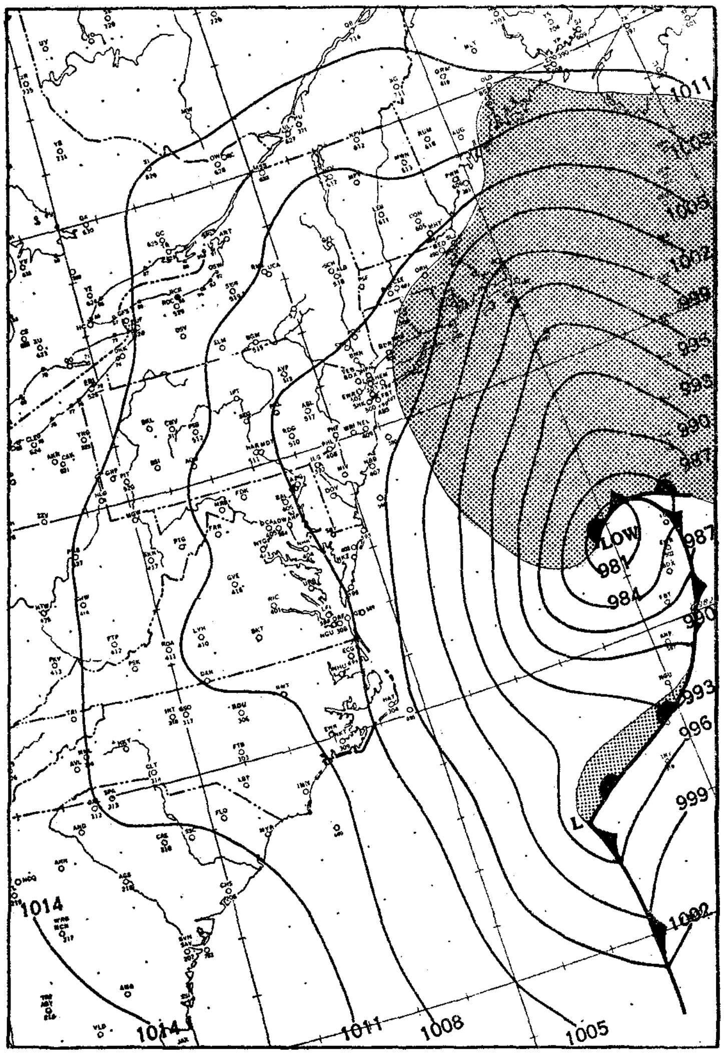

FIGURE 6.—Surface chart, 2130 GMT, February 27, 1952.

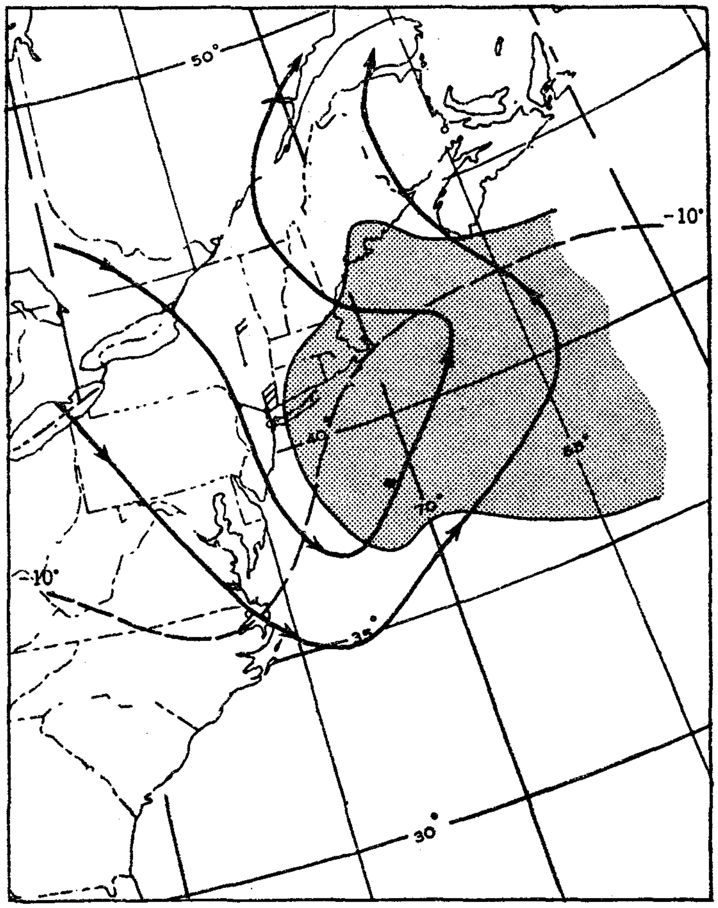

FIGURE 7.—700-mb. chart, 2100 GMT, February 27, 1952. Solid lines show airflow parallel to the contour lines. Isotherm for −10° C. Precipitation at 2130 GMT

is the air trajectory: in all zones, except near the ridge, southerly flow is usually associated with heavy (amounts), westerly with moderate (amounts) and northerly with light (amounts)". These observations are particularly applicable to the 700-mb. level but hold, in this storm, for the 500-mb. level as well.

When the forecast was being made for the Washington area there was evidence that the precipitation had already approached about as close to Washington as it would during this storm. This can be inferred by inspecting figures 2 and 3, which show a relationship between the precipitation and the air flow at 700 mb. Figure 2 by itself, however, is not sufficiently informative, but when interpreted in light of the knowledge that the trough over the Great Lakes was moving eastward while the wave in the southern end of the trough was moving northeastward, it foretold that precipitation was unlikely to come much closer to Washington. Thus the forecast for the Washington area could be justified.

Six hours later (fig. 3) the nonoccurrence of precipitation with westerly winds was more clearly delineated. A strange circumstance is depicted on this map wherein the winds from Washington northeastward show poor agreement with the contours as drawn for the reported heights. In spite of this anomaly the precipitation ceases where westerly winds are reported.

Incidentally the surface precipitation areas were drawn in by the analyst without reference to the 700-mb. flow; the 700-mb. contours are copied from charts drawn by a different analyst on duty that day. In other words, the combination of rain, snow, and air flow is a juxtaposition of 2 different maps independently drawn. Again in figures 5 and 7, drawn in the same independent manner, the surface precipitation ends in the region of the leading edge of the westerly flow.

THE STORM AT CAPE COD

Figures 4, 5, 6, and 7 show some details at the surface and the 700-mb. level as the deepening storm approached Cape Cod. By 1500 GMT on the 27th (fig. 4), the advancing line of snow had already reached Nantucket. A knowledge of the path so far taken by the center and the projected path indicated that the southern and eastern shore of the New England States would receive precipitation. It could be presumed that the duration and intensity of the fall might be greater than was reported along the mid-Atlantic coast. The first observation was so for a number of reasons, chief among which was the direction of movement of the storm as it was related to the land mass of the northeastern States (the land extends farther eastward with increasing latitude). The second was also true because the storm had been deepening and the continuation of this trend could be expected to bring more moisture into the storm.

A comparison of figures 2 and 5 shows changes at the 700-mb. level which supported the preliminary concepts gained from an inspection of the surface maps. The most important change was the increasing cyclonic flow representing an increasing moisture supply and greater horizontal convergence to aid in lifting the moisture. As the storm moved northeastward the westerly winds at 700 mb. (fig. 2) over New England shifted to easterly (fig. 5) and finally southerly and southeasterly (fig. 7). This changing and intensifying air flow caused heavy snowfall at Cape Cod and a rapid spread of the precipitation to the north and northeast along the coasts of New England and Nova Scotia. Anticipation of such changes in the flow pattern seems to be prerequisite to correctly forecasting the precipitation pattern in well developed storms.

There were certain circumstances, in this case, which contributed to the production of snow at Cape Cod. Usually, coastal storms move north or northeast along, or off, the coast of the United States bringing snow to the adjacent land areas and, usually, rain to the Cape Cod-Nantucket region. This extreme easterly bit of land is usually in the warm sector (or sufficiently close to it) where the air is above freezing because of Gulf Stream modification. At other times, the Cape is in the region of above-freezing modified polar air. On still different occasions, the tip of the Cape is just on the western fringe of the snow area associated with a Low (far out at sea) moving northeastward. This situation usually brings light snowfall to the vicinity of the Cape.

This storm differed from the last described situation in a number of ways; first, the Low moved on a course with increasing northerly component with time; secondly, it deepened rapidly while moving close to the Cape and, at the same time, decreased its rate of progression. Along with a good supply of tropical air to the east of the storm track the situation was influenced by the steep slope of quite cold air to the west of the center. The strong southerly flow from the surface to above the 500-mb. level and the steep mass of cold air just west of the trough, produced two results: strong, increasing horizontal convergence in the warm air plus extensive and rapid lifting by the cold air over and above that related to the cold front. This accentuated lifting process combined with the strong infeed of moist tropical air provided just about optimum conditions for the production of precipitation, as the data from Nantucket certainly seem to prove.

The reports from Portland, Maine, Boston and Nantucket, Mass., are illustrative of the sharp gradient of snowfall previously mentioned. Portland received a total of 1.5 inches during the storm while Boston measured 5.2 inches but Nantucket received 14.9 inches on the 27th, 5.2 inches on the 28th, and an additional 1.3 inches on the 29th when a minor disturbance passed to the south of the Cape. The official storm total was 20.1 inches.

Nantucket had a snow cover of 3 inches on the evening of the 26th, 13 inches on the 27th, 20 inches on the 28th, and 17 inches on the 29th. Along with the previous snowfalls of 4.9 inches on the 18th and 10.1 inches on the 21st, the ground was covered with snow from the 18th to the end of the month. The comment at the end of the Local Climatological Data (Feb. 1952) for Nantucket stated, "Total snowfall for the month was 36.4 inches, which was the largest ever recorded for the month of February. The 20.1-inch fall on the 27-28th was the greatest ever recorded in any 24-hour period. On the 28th, the depth on the ground reached 23 inches, also an all-time record for any month."

Strong winds accompanied the snow at Nantucket on the 27th when the fastest mile was 61 m. p. h. from the northwest with an average for the day of 26.8 m. p. h. On the 28th, the fastest mile was 50 m. p. h. from the northeast with an average for the day of 23.1 m. p. h. This unhappy combination of a heavy fall of dry snow and gales brought considerable damage and hardship to the residents of the area.

According to the local papers the resulting drifts, ranging from 10 to 15 feet, marooned an estimated 3,000 automobiles between the Cape Cod Canal and Provincetown, R. I., during the time the storm was raging near the Cape. Innumerable homes were without light and heat as power lines went down. Power company officials estimated 80 percent of the Cape's electric power was cut off at one time (about as great as the power failure during the 1944 hurricane). Storm damage was estimated to be near $500,000 and the death toll as of the 29th stood at 13.

REFERENCE

W. H. Klein, "An Objective Method of Forecasting Five-Day Precipitation for the Tennessee Valley," *Research Paper No. 29*, U. S. Weather Bureau, Washington, D. C., April 1949.

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